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PERFORMANCE ANALYSIS OF "MECHANICAL STEERING SYSTEM" FOR EFFORTLESS OPERATION OF BOATS"

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ABSTRACT

This research paper aims for product up-gradation, "To exist is to change, to change is to mature, to mature is to go on creating oneself endlessly", This we can apply to every aspect of life in an ever-changing world, therefore it is untiring work to upgrade the existing product with changing technology, competitors response to stay in the business.

Looking at the report published, boat market size is expected to expand, from 2021 to 2028 with a 4.5% rate.[15]

Considering the threats of a better product launched by competitors as well as a policy to continuous improvements, analysis for a better product was carried out.

KEYWORDS: Analysis, Boat, design, planetary, steering

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Original Article

1. INTRODUCTION

Leisure Boating is used for travelling for recreation of business, they are powered, sailing or rowing/paddling. The most common activities are sports/fishing. *There are millions across the world.*

Boat parts manufacturer around the world are developer, manufacturer and supplier of parts used in boats and boating as well they have to evolve their product to keep their market share as high as possible, which we intend to do through this project.

This study aims to analyze and conclude with a better product used in the steering system.

A **boat** is a watercraft of many different sizes and types smaller than a ship, can be found in inland waterways, coastal areas, with differently built according to local tradition.

Mostly, boats are propelled by power (diesel of electric engine), Sailing by wind, and manpower - rowboats and paddle boats.

Terminology-:

- HULL it is the main body of boat according to capacity and buoyancy.
- KEEL it is perpendicular structure lengthwise fixed.
- BOW the front end,

- STERN aft end.
- STARBOARD / PORT front right side also called starboard and the left is port.
- GUNWALE top edge,
- CLEAT – metal part by which ropes are fastened.
- PROPELLER forward back and rotating the boat.
- RUDDER is used to steer the boat.

Rowing is the process used repeatedly regularly to steady the boat and maintained steady state.

Yawing-:

Motions of body by the six degrees of freedom,

3 rotational (Pitch, Roll, Yaw),

3 Translational (Heave, Sway, Surge)

Z axis is the vertical reference of vessel.

Steering System-:

The aim of steering arrangement is to turn the rudder of a boat with manual power remotely.

Rudder is the part of the ship to control steering process, through a medium, A rudder used to give direction to fluid to facilitate yawing or turning. This is operated by helmsman through series of system, either mechanically / hydraulically or electric.

> *"Steering system is an arrangement to be assembled with all components necessary to transmit remote manual effort to the rudder,used to control steering*."

As a manufacturer of steering system, looking at study of global market potential, and upholding existing features, a steering system to operate with less effort about half of an existing product will help in marketing and sale to acquire market share.

The component of a steering system to study and evolve is the "**HELM".**

II – LITERATURE REVIEW

A survey of, published articles on studies conducted for different existing steering system used in Marine application, focusing on making it more effortless

Mr. Li Ting-Yun, have published in, 2019 a research and Simulation about Marine Electro-hydraulic Steering Gear System.

By selecting typical operating condition and deciding the parameter with an aim to work out the effect of volume change and loading change of electro-hydro system. Simulation of system is been carried out. [7]

Mr. Goran Vukelic,did a case study on topic of a cracked speed boat steering wheel. October 2015,

The study is conducted of a cracked steering wheel, on a speed boat, with results of the experiment found that the material is aluminum alloy and cracks emanated, due to over tightening of bolts, these cracks initiate points for crack growth[4]

Mr. Fujio Ikeda, Published a paper for pleasure boats steering system, as a study of steering system algorithm

Manual Hydraulic Steering Mechanism (MHSM) handling can be better by replacing Electronic Control Steering Mechanism (ECSM). [5]

Mr. Lv Weifeng, Mr. Sun Chuang, Mr. Wang Chuang, Mr. Lu Guangxing and Mr. Xu Bin have published on the topic Hydraulic Steering Gear System simulator in Marine Engineering, January 2017,

The model, simulation and application related to steering gear hydraulic system is established, the pump-control type steering gear, and the model combined with ship. Autopilot simulator used for training purpose. [8]

Mr. Gheorghe Samoilescu, Mr. Dumitru Lorgulescu, Mr.Robert Mitrea, Miss. Laura D. Cizer of Mircea cel Batran Naval Academy, Published in researchgate, about Steering Gear considering Modern Navigation.

The paper presents different aspects related to steering system, automation and modern propulsion. Keeping check on its price, consumption, efficiency, etc.),

The steering system performs the rotation during mooring and unberthing operations, the interface provides access to its basic systems. The purpose is giving alarms and monitoring, and control, the operation of the ship.[9]

Mr. Unar & Murray-Smith literature reviewed published in July 1999,

With series of simulation of ship steering control system, and their dynamic properties (vessel itself), the studies and outcome of radial basis function network and local model networks represent dynamics. Performance is demonstrated. [6]

Mr. Muhammad Ejaz, Mou Chen literature reviewed published in 2017, the autopilot system using fuzzy gain of a scale down model of control of a ship is presented, and found more accurate than the one in use.[10]

Mr. Xia Ye, literature reviewed, published in 2018, a case study of hydraulic Steering system.

The case study hydraulic steering system failure, to avoid failure which leads to accidents, can be controlled at the process of designing, selection and manufacturing, and quality control, maintenance.[11]

Mr. D.P. Dave and Dr. A. A. Ghatol literature reviewed, published in with the topic name "Modeling and Simulation of Marine Control Systems – A Review"

This is useful for a researcher to start-up.the research work.[14]

III – METHODOLOGY

To ensure sales volume in the future market, with an extra feature of effortless operation, a study is conducted on published papers as above and a decision made to carry on a project to analyze to fill this gap.

The key performance parameter of a steering system is the efforts requires to operate, therefore, conduct performance analysis of existing steering system, recommend and implement the changes in design to make system

effortless by about ½ of existing efforts, to sustain market competition.

A. Part Selection

A Steering System consists of following major items :

- Drag link
- Steering Helm
- Wheel
- Push Pull Cables
- Accessories

The scope to upgrade a system is limited to its components, where above items to be reviewed to go under a change, Drag link, wheel, push pull cables and accessories have very less scope to go under design revision compared to helm, it can analyses for an up gradation of substantial applied torque reduction to be effortless.

Helm, consider it a gearbox, is used to apply operating torque multiplying by its gear ration to the applied force. This can be used in manufacturing process or in automobiles.

Redesigning the mechanism to have better output torque to ease the helmsman with less input efforts.

B. Mathematical Calculation

A Steering System

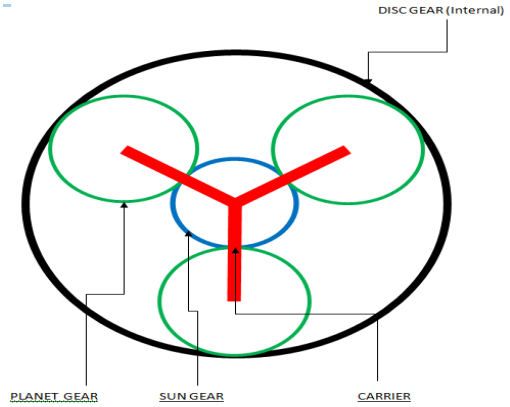
The helm is the gearbox directly fitted with the steering wheel at dashboard panel, convert rotary motion to push-pull action of the steering cable, through a drum fixed inside the helm. There are different type of helm, sliding, rotary, planetary. with different advantages and disadvantages.

Planetary gear type: This is a compact gearbox to take less apace at the panel. 3 or more gears rotate internally with cable drum around through rotary motion of the wheel.

The system is shown as bellow, It consists of

- Gear A (SUN)
- Gears B (PLANET)
- Gear C (RING)
- Carrier D (DRUM)

In our helm under study the ring gear is fixed, gear A is the input, and the output drum is the carrier.



The planetary gear train in use is of a set of 3 planet gear revolves around in ring gear. They are connected with drum as carrier, The sun gear act as input pinion to rotate planet gears, they make such a coupling that they do not have any slip. The pitch circle of planet gear traces a curve epicycloids, In our case, ring gear is fixed.

Gear ratio -:

The gear ratio of the gearing system depend on different configuration of input and out puts. *Sun*: The central gear Gear ratio of a planetary gear train, calculated with following two equations, Sun-planet and Planet-ring, respectively

$$N_s\omega_s + N_p\omega_p - (N_s + N_p)\,\omega_c = 0$$

$$N_r\omega_r + N_p\omega_p - (N_r + N_p)\,\omega_c = 0$$

Angular velocities are $\omega_r\omega_s\omega_p\omega_c$

Ring, Sun, Planet, Carrier respectively.

$N_rN_sN_p$ (No. of teeth of the *Ring*, *Sun Planet gear* respectively)

from which we can derive the following:

$N_s\omega_s + N_r\omega_r = (N_s + N_r)\,\omega_c$

$\omega_s = \frac{N_s+N_r}{N_s}\omega_c - \frac{N_r}{N_s}\omega_r$

$$\omega_r = \frac{N_s + N_r}{N_r}\omega_c - \frac{N_s}{N_r}\omega_s$$

$$\omega_c = \frac{N_s}{N_s + N_r}\omega_c - \frac{N_r}{N_s + N_r}\omega_r$$

and

$$-\frac{N_r}{N_s} = \frac{\omega_s - \omega_c}{\omega_r - \omega_c}$$

Considering $\omega_r \neq \omega_c$.

Torque ratios-:

Two speed must be known for third The torque are

$$T_r = T_s \frac{N_r}{N_s}$$

$$T_r = -T_c \frac{N_r}{N_r + N_s}$$

$$T_c = -T_r \frac{N_r + N_s}{N_r}$$

$$T_c = -T_s \frac{N_r + N_s}{N_s}$$

$$T_s = T_r \frac{N_s}{N_r}$$

$$T_s = -T_c \frac{N_s}{N_r + N_s}$$

They are T_r— RING,

T_s— SUN,

T_c— CARRIER.

Applied torque to gear train, Output torques have reverse input torques signs.

Depends on configuration, equation are modified

Ratio with fixed carrier

$$\boldsymbol{R = \frac{\omega_s - \omega_c}{\omega_r - \omega_c}}$$

Angular velocity ω_c=0,

$$R = \frac{\omega_s}{\omega_r}$$

therefore $-\frac{N_r}{N_s} = \frac{\omega_s}{\omega_r}$

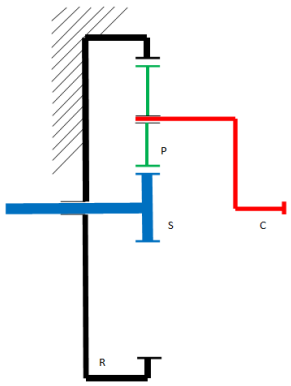
Ratio with fixed ring

Angular velocity ω_r=0,

$$R = \frac{\omega_s - \omega_c}{-\omega_c}$$

or $\frac{\omega_s}{\omega_c} = 1 - R$

therefore $1 + \frac{N_r}{N_s} = \frac{\omega_s}{\omega_c}$



Ratio with fixed Sun gear

Angular velocity ω_s=0,

$$R = \frac{-\omega_c}{\omega_r - \omega_c}$$

$$1 - \frac{1}{R} = \frac{\omega_r}{\omega_c} \text{therefore} \quad 1 + \frac{N_s}{N_r} = \frac{\omega_r}{\omega_c}$$

IV – ANALYSIS

Comparative analysis of the exercise to upgrade existing helm is as follows,

GEAR RATIO CHANGE:

GEARS	EXISTING	NEW
Ring gear no. teeth	61	61
Sun gear no. teeth	19	11
Planet gear no. teeth	23	25
Ratio (1:X)	4.21	6.315

Gear ratio reduction achieved = 50 %

A prototype is been manufactured with new gear ratio to compare gain in torque,

TEST RESULTS:

Sr. No.	Torque required (Existing)	Torque required (NEW)
1	3.78	2.20
2	3.43	2.00
3	3.64	2.12
4	3.91	2.28
5	3.70	2.16
Average N-m	3.69	2.12

Effort reduction achieved: 42 %

- Torque requirement is improved from 3.69 N-m to 2.12 N-m,
- Satisfy condition of operation of planetary gear mechanism,
- The concept of planetary remains as three set of gears
- gear train as a developer, manufacturer and suppliers of boat parts, specially keeping the cost of manufacturing in control and changing minimum parts to increase the torque at output, is to consider a change in gear ratio. This offers a better product to sustain the market.

V- CONCLUSIONS

A 42 % of reduction in efforts is achieved, with Upholding existing features, and

- A focuses on the key global manufacturers,
- and development plans in the next few years,
- also the results of performance analysis of modified product

It is time to take the decision, to produce the helm with new gear-train And offer the changes for a better product to Market as this upgrade, *"effortless operation, at helm by half".*

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